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ILWOG 42 Conference Proceedings - Status of Solid Debris Collection for Radiochemical Diagnostics and Measurements on NIF

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ILWOG 42 Conference Proceedings – Status of Solid Debris Collection for Radiochemical Diagnostics and Measurements on NIF

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Radiochemical measurements of NIF capsule performance and the use of ignition capsules to perform Stewardship-related cross section measurements require the development of a method of collecting post-explosion debris. NIF experiments will produce thermonuclear ignition on a "laboratory" scale, in which an incredibly high neutron flux is generated inside the fusion capsule. Introduction of a detector isotope into the capsule ablator will allow us to diagnose the thermonuclear yield of the capsule and may provide the means by which we can measure valuable experimental cross-sections for neutron reactions on radioactive species. Detector isotopes can be loaded in the innermost layer of the capsule ablator at concentrations of up to~10^{15} atoms before they affect capsule performance [(1)]. Collection and analysis of the post-ignition debris will help determine various diagnostic parameters such as yield, implosion asymmetry, and fuel-ablator mix.

The challenges associated with debris collection are complex, including the uncertainty of plasma condensation chemistry, debris formation and ablation in a high radiation field, and transport/collection efficiency. Additional constraints include collector accommodation amidst a variety of diagnostic equipment and sensor packages. Solid collection feasibility studies have been on-going through a collaborative, parallel effort between LANL, LLNL and the Colorado School of Mines. These studies have included material optimization, i.e. what will make the best collector under various fluence conditions and what geometry will optimize collections? Preliminary debris characterization and distribution studies at NIF have begun using the Al blast shields (1 mm thick, 5.56 cm^2) that covered the In foil used for neutron activation detector (NAD) diagnostics. The NADs were positioned 25 or 50 cm away from the target in either the equatorial or polar plane, respectively. Disposable debris shields (DDS) that were used to protect the final optics assembly (FOA) were also evaluated to determine potential collector locations and maximum transport distance (DDS was ~7 m from target chamber center, TCC). Optical images and non-destructive (or minimally destructive) element analysis have been performed using Secondary Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS). The goal of this work is to determine:

1. What elements are present on the shield post-shot?
2. What is the debris origination; i.e. target versus surrounding structural/mechanical debris?
3. What is the particle size distribution and impact velocity?
4. How do changes in surface morphology relate to surface temperature and energy density?
5. How much debris was collected from the target chamber center (TCC)?

Twelve Al shields and two sets of DDS shields have been imaged and various elements associated with structural materials have been identified on both. Gold is only present in the NIF chamber from the holhraum, and quantifying the amount of gold collected on a surface can be used to evaluate collection efficiency as a function of distance from TCC and solid angle covered by the shield. Dissolution studies are in progress to quantitatively determine Au concentration on each blast shield and DDS. Initial results indicate that the DDS shields are too far from the TCC for adequate debris collection, but provide critical information for the NIF optics research group. The DDS shields are not replaced between shots with the assumption that the laser beam will be self-cleaning in the transmission window, which results in major cost-savings for the project. However, accumulation of debris can lead to decreased transmission efficiency and current impact crater analysis studies will help determine the useful lifetime of each DDS shield. The Al shields were used only once and the shot profiles ranged in energy from 50 to 900 kJ. We are currently working with a metallurgist to evaluate the temperature and energy profiles for each shield to determine minimum collector distances, especially for higher yield shots. In conjunction with this, alternate materials will be fielded as blast shields when NAD shots are resumed (summer 2010) to determine the effectiveness of other materials, in terms of collection efficiency, stability and dissolution chemistry. We have also proposed ride-along experiments where alternate metal foils (for example, Ta, V, and Nb) will be fielded as the end-cap on the passive particle detector (PPD) assembly. This is a circular mount that is attached to the end of the diagnostic insertion module (DIM) and is currently used for fielding other diagnostics. Several pairs of metal foils will be fielded in a similar configuration so that their characteristics can be evaluated and compared with the large data set we currently have on Al.

In combination with debris collection and characterizations studies performed at other laser facilities, it is clear that several collectors must be fielded during ignition shots to maximize collection efficiency. The photon flux at the pole will ablate the collector material ahead of the debris implantation, requiring the use of a secondary collection apparatus to collect both the debris and ablated material (current assembly under development at LANL). Debris traveling in the equatorial plane can be passively collected on catchers mounted on a collar assembly inserted around the DIM.

References

1. **Fortner, R., et al.** *Ignition Failure Mode Radiochemical Diagnostics.* Lawrence Livermore National Laboratory. 2007. UCRL-TR-230178.

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